RESEARCH DEPARTMENT

VAROTAL V
A 10 TO 1 ZOOM LENS FOR THE IMAGE ORTHICON FORMAT
(No. 617566)

Report No. T-112
(1963/36)

W.N. Sproson, M.A.

D. Maurice
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SUMMARY

Measurements are reported on the zoom lens Varotal V. These include modulation transfer factor, vignetting, transmission and veiling glare and geometrical distortion. An overall assessment based on sharpness and vignetting is given and comparisons are made with other lenses, both of fixed focal-length and of varifocal length.

1. INTRODUCTION

Varotal V is the first British 10 to 1 zoom lens to be released. Previous zoom lenses of this zoom range have been of French origin.[1,2] It is therefore of considerable interest to compare this lens with the Type 10X35A made by M. Angenieux particularly as the specification is in many ways similar. A brief specification of the Varotal V zoom lens is as follows:

Focal length range	40 mm to 400 mm
Maximum aperture	*f*/4
Field covered	24 mm × 32 mm (image orthicon format)
Minimum focusing distance	1·83 m

The results of the measurements will be described under the headings, (a) Modulation Transfer Functions; (b) Vignetting Characteristics; (c) Transmission and Veiling Glare; (d) Geometrical Distortion.

2. RESULTS

2.1. Modulation Transfer Functions

Measurements of the modulation transfer function were made at seven focal-length settings (namely 40, 59, 86, 126, 186, 272 and 400 mm) for a test object effectively located at infinity. The setting-up procedure was the normal method of successive approximations, namely, the back-working distance was adjusted for best imagery at the short focal length of the zoom range, and the focusing control on the lens itself was adjusted at the long focal-length end. The modulation transfer curves at full aperture are shown in Figs. 1 to 7. The distinction between the sagittal and

tangential modulation transfer factors at 0 mm (i.e., on the optical axis) is quite arbitrary. It is due principally to errors of alignment in the construction and setting-up of the individual optical components of the lens. The results at an aperture of $f/5{\cdot}6$ are given in Figs. 8 to 14. These curves represent normal zoom operation and no allowance is made for any tracking error. No tracking error was in fact observed at full aperture. The measurements at $f/5{\cdot}6$ were taken with the lens as set-up at full aperture for back-working distance and focus setting.

A concise summary of the information offered in Figs. 1 to 14 is given in Fig. 15 which shows the modulation transfer factor in the mid-field position at a spatial frequency of 8 cycles/mm which corresponds to the video cut-off frequency of the British 405-line television system. The overall assessment of the lens is given in Section 2.5.

Time did not permit measurements of modulation transfer functions for the case of a test object at a finite distance. It is understood that the design of the lens gives minimum aberrations for a test object located at a distance of 15 to 20 ft (4·57 to 6·10 m). If this is so, then the results quoted in Figs. 1 to 14 are likely to be slightly inferior to those holding under most practical conditions where the test object (or scene) is not located at infinity.

It was ascertained that the manufacturer's claim of a near working distance of 6 ft (1·83 m) is correct.

2.2. Vignetting Characteristics

These have been measured at full aperture ($f/4$) and at $f/5{\cdot}6$. Fig. 16 shows the relative image illumination at seven focal lengths for an aperture of $f/4$ and Fig. 17 shows the peripheral illumination as a function of focal length for both apertures. A minimum peripheral image brightness occurs at a focal length of 59 mm when the lens operates at full aperture. The effect of vignetting on the subjective assessment of the image formed by the lens is given in Section 2.5.

2.3. Transmission and Veiling Glare

Special techniques have been employed with this zoom lens to ensure that it shall have a relatively high transmission, viz. the use of 2 or 3 layer dielectric coatings on the surfaces of the lens elements and the choice of glasses with low absorption. As a result, the transmission of tungsten white light is over 80%, which is a very good figure for a lens of this complexity. Table 1 gives the full results.

Taken in conjunction with a geometrical aperture of $f/4$, the photometric aperture is evaluated at T/4·44.

When the transmission of a lens is high, the veiling-glare index is usually low and this lens follows the normal trend. The veiling glare index to tungsten white light varies from 1·2% (at the short focal length end) to 0·85% (at the long focal length end). Fig. 18 shows the complete results for red, green and blue illumination

TABLE 1

Type of lighting	Transmission %
White	81
Red	86
Green	80
Blue	69

as well as tungsten white. Veiling glare indices of the magnitudes shown in Fig. 18 are near to the figure specified by the BBC lens specification[3] for fixed focus lenses, i.e., a maximum of 1%.

2.4. Geometrical Distortion

The geometrical distortion of most fixed focus lenses is not greater than about one tenth of that specified in the BBC lens specification[3] so that it has not usually been necessary to report on this aspect of lens performance. The situation with zoom lenses is somewhat different[4] and it has been thought desirable to make measurements particularly at the two extremities of the range of focal lengths where the geometrical distortion is likely to be most severe. Fig. 19(a) shows the error in the image position plotted against the calculated position (for a distortionless lens) at the short focal length and Fig. 19(b) shows the results at the long focal length. The distortion changes in sign from 'barrel' distortion at the short focus end to 'pin-cushion' distortion at the long focus end.

The manner of showing the results in Fig. 19 is not the one given in the BBC lens specification. This is concerned with relative displacement and Table 2 shows the results set out in this way.

TABLE 2

Geometrical Distortion

<table>
<tr><th>Field position (mm)</th><th>f = 40 mm
Relative displacement
$\delta\tau/\tau$ (%)</th><th>f = 400 mm
Relative displacement
$\delta\tau/\tau$ (%)</th><th>TV 88/2
Specification</th></tr>
<tr><td>2</td><td>+3</td><td>-0·4</td><td rowspan="7">less than 1%</td></tr>
<tr><td>4</td><td>+3·2</td><td>-0·6</td></tr>
<tr><td>6</td><td>+3·2</td><td>-0·7</td></tr>
<tr><td>8</td><td>+2·7</td><td>-0·8</td></tr>
<tr><td>10</td><td>+2·1</td><td>-0·7</td></tr>
<tr><td>12</td><td>+1·3</td><td>-0·6</td></tr>
<tr><td>14</td><td>+0·7</td><td>-0·3</td></tr>
<tr><td>16</td><td>0</td><td>0</td><td></td></tr>
<tr><td>18</td><td>-0·9</td><td>+0·4</td><td rowspan="2">less than 5%</td></tr>
<tr><td>20</td><td>-1·9</td><td>+0·8</td></tr>
</table>

Table 2 shows that the lens conforms to the BBC specification at the longest focal length but not at the shortest focal length. Two points should be made, however; first that the BBC lens specification TV 88/2 does not refer to zoom lenses and second, that the relative displacement criterion places very stringent limits on displacements near to the optical axis (i.e. near to 0 mm in Table 2) and appears to be very tolerant indeed of geometrical errors in zone 3, i.e., greater than 16 mm. It may be that some revision of the specification is required to avoid the features just mentioned. It is felt that the criterion for geometrical distortion should be based on the ability to image (say) a rectangular grating pattern without any perceptible curvature of the straight lines; it is not immediately apparent that the tolerances laid down in specification TV 88/2 will achieve this over the whole field although they probably suffice in zones 1 and 2.

2.5. Overall Assessment

The integration of a modulation transfer curve up to the cut-off frequency gives a result proportional to the gradient of an equivalent time function (the response to unit step) at the 50% point and this has been found to correlate well with the subjective impression of sharpness.[5] Further integration can take into consideration various parts of the field and in this way an index[6] can be determined which gives the effect of sharpness over the whole field. A possible defect of this index has recently come to light, namely, that the index is not explicitly concerned with rates of change of sharpness over the field. Some evidence has been offered which indicates that poor peripheral sharpness is easily perceptible when the resolution of the central parts of the field (e.g. zones 1 and 2) is particularly good. The same level of poor peripheral sharpness may well be much less obvious if the resolution over zones 1 and 2 gradually diminishes. This is a possible criticism of the image quality given by Varotal V at certain settings of focal length and aperture (59, 86, 126 and 186 mm at $f/4$). Nevertheless, it is considered that the index of performance is a good general guide to the image quality. The sharpness of the image at and near to the periphery of the field is not usually of great importance and the BBC specification for lenses does not lay down any standards of resolution in zone 3.

The overall assessment expressed in liminal units is given in Fig. 20 for the performance at full aperture and in Fig. 21 for the performance at $f/5{\cdot}6$. The impairment due to vignetting is also shown in Figs. 20 and 21. These results establish a high level of image quality for zoom lenses in that the impairment due to sharpness is less than 1 limen for a range of focal lengths from 40 to 80 mm at full aperture and is only just over 1 limen from 80 mm to 200 mm. At $f/5{\cdot}6$ only over a small part of the range (viz. 350 to 400 mm) does the impairment exceed 1 limen; in fact, from 40 mm to 120 mm the sharpness impairment at $f/5{\cdot}6$ only just exceeds 0·5 limen. The impairment due to vignetting is very satisfactory with the exception of a small range of focal lengths near to 60 mm where the impairment exceeds 1 limen at full aperture. At $f/5{\cdot}6$ the impairment due to vignetting is negligible over the whole zoom range.

3. COMPARISON WITH OTHER LENSES

3.1. Comparison with Fixed Focus Lenses

For the purposes of this comparison, the range of Ortal lenses is considered; these lenses have been in use in the Television Service for some time and are known to

give images of very good quality. The quantative results are given in Fig. 22 and it will be seen that the impairment due to sharpness of Varotal V is in no case more than 1 limen greater than that due to an Ortal lens of corresponding focal length. At focal lengths of 50 and 200 mm the differences are only about 0·5 limen. The total impairment due to both sharpness and vignetting of Varotal V is also shown in Fig. 22. The maximum difference occurs at 59 mm and is about 1·25 limen. It should be pointed out that the impairment in the performance of the Ortal lens at *f*/4 is exclusively due to sharpness: there is no impairment due to vignetting.

3.2. Comparison with Other Zoom Lenses

The comparison of greatest interest is that with the Angenieux Type 10X35A zoom lens which has a somewhat similar specification. Numerical results are given in Fig. 23, which also includes the performance of Varotal III. Dealing first with impairment due to sharpness, the Varotal V is seen to be slightly superior to the Angenieux 10X35A over practically the whole of the range of focal lengths. At a focal length of 270 mm the sharpness impairment is the same for the two ten-to-one zoom lenses; the maximum difference occurs at focal lengths of 40 and 126 mm and is about 0·5 limen. In practical terms, this means that the overall sharpness of the two images is nearly the same, but with a slight advantage to Varotal V.

If the total impairment is considered, then Varotal V has a more definite advantage owing to its better vignetting characteristic: differences vary from 0·5 to 1·2 limen over the range of focal lengths common to the two lenses (i.e., 40 to 350 mm). Other features are summarized in Table 3.

TABLE 3

Comparison of Some Features of Two 10-to-1 Zoom Lenses

Feature	Angenieux 10X35A	Varotal V
Maximum geometrical aperture	*f*/4·5	*f*/4
Transmission to tungsten white light	64%	81%
Photometric aperture	T/5·6	T/4·4
Veiling glare index (tungsten white light)	1·2 to 2·2%	0·85 to 1·2%
Near focusing distance	0·95 mm	1·83 mm

Table 3 shows that with one exception, the Varotal V is somewhat better than the Angenieux zoom lens. The one exception is important, however, because the Angenieux lens can focus down to half the distance of the Varotal lens. The weighting to be attached to this feature will clearly depend on the use to be made of the lens. Except in those applications where ability to focus down to 3 ft (0·95 m) is essential,

the measurements performed on Varotal V indicate that it is the better of the two lenses. One mechanical feature should also be mentioned: Varotal V is a constant volume device and operation of either the zoom or the focus control does not cause air to be pumped into and out of the lens. This should help in keeping the internal surfaces clean. The focus control on the Angenieux 10X35A causes the front element to move by about 1¾ in (44 mm).

Comparison of Varotal V with Varotal III (Fig. 23) shows that the increased zoom range of Varotal V has been achieved with no loss of image quality; in fact Varotal V gives a better image at all corresponding focal lengths. It is only proper to point out, however, that Varotal III has on average a larger focal length than Varotal V and on this account would be expected to have aberrations of greater magnitude. This is so because for a given lens design, and a given image format, the aberrations increased in proportion to the focal length.

4. CONCLUSION

Varotal V is a zoom lens which sets a new standard of performance for such lenses in respect of transmission, veiling glare and image sharpness. Although it is inferior to fixed-focus lenses, the gap has been narrowed and it is no longer easy to distinguish between an image formed by a first grade fixed-focus lens and that produced by Varotal V. For applications where the nearest focusing distance exceeds 6 ft (1·83 m) the tests on the prototype indicate that this lens can be used to give a very good image (i.e., impairment of not much in excess of 1 limen) at full aperture over most of the zoom range; when used at one stop from its full aperture it is considered unlikely that any fault will be found with the image quality.

5. REFERENCES

1. 'The Angenieux 10-to-1 Zoom Lens (No. 923851)', Research Department Technical Memorandum No. T-1043.

2. 'The Angenieux 10-to-1 Zoom Lens for the Image Orthicon Format, Type 10X35A (No. 1016554)', Research Department Technical Memorandum No. T-1054.

3. BBC Specification of Lenses for Television TV 88/2.

4. 'A Comparison of Two Zoom Lenses', Research Department Report No. T-046, Serial No. 1954/21.

5. Sproson, W.N., 'The Subjective Sharpness of Television Pictures', Radio and Electronic Engineer, April 1958, Vol. 35, No. 4, pp. 124 - 132.

6. Sproson, W.N., 'New Equipment and Methods for the Evaluation of the Performance of Lenses for Television', BBC Engineering Division Monograph No. 15, December 1957.

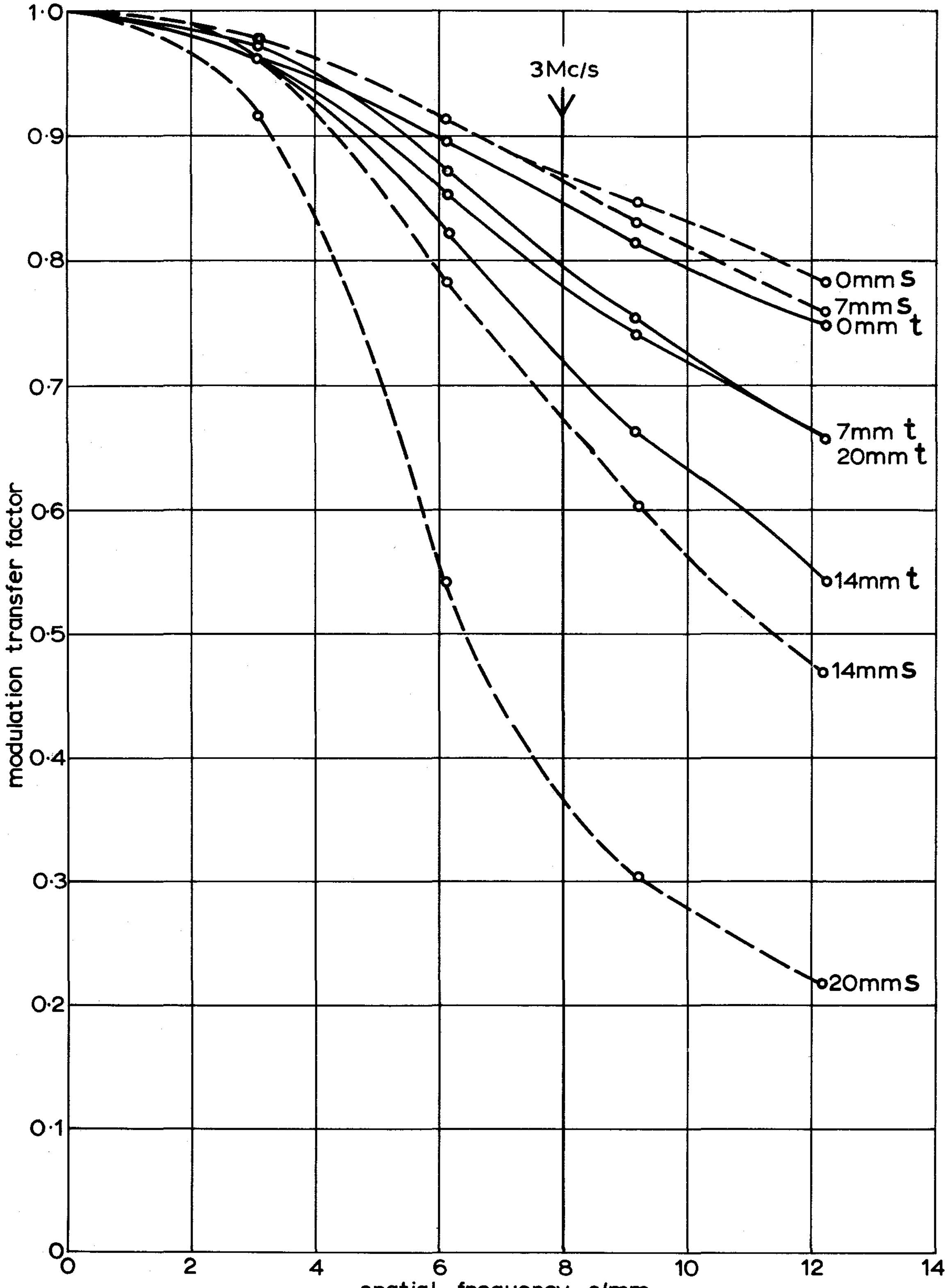

Fig. 1

Modulation transfer curves

focal length 40mm
aperture f/4

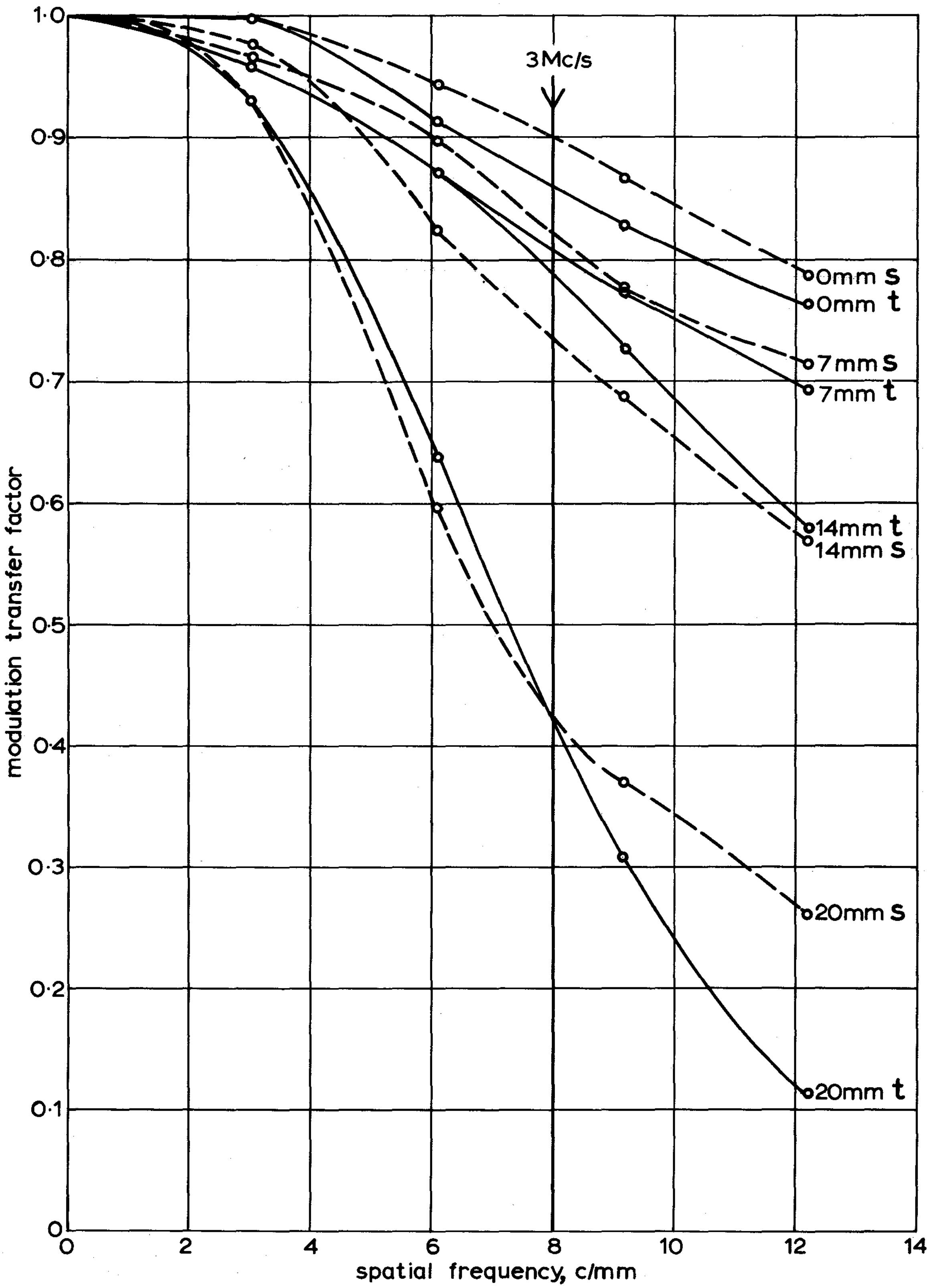

Fig. 2

Modulation transfer curves

focal length 59mm

aperture f/4

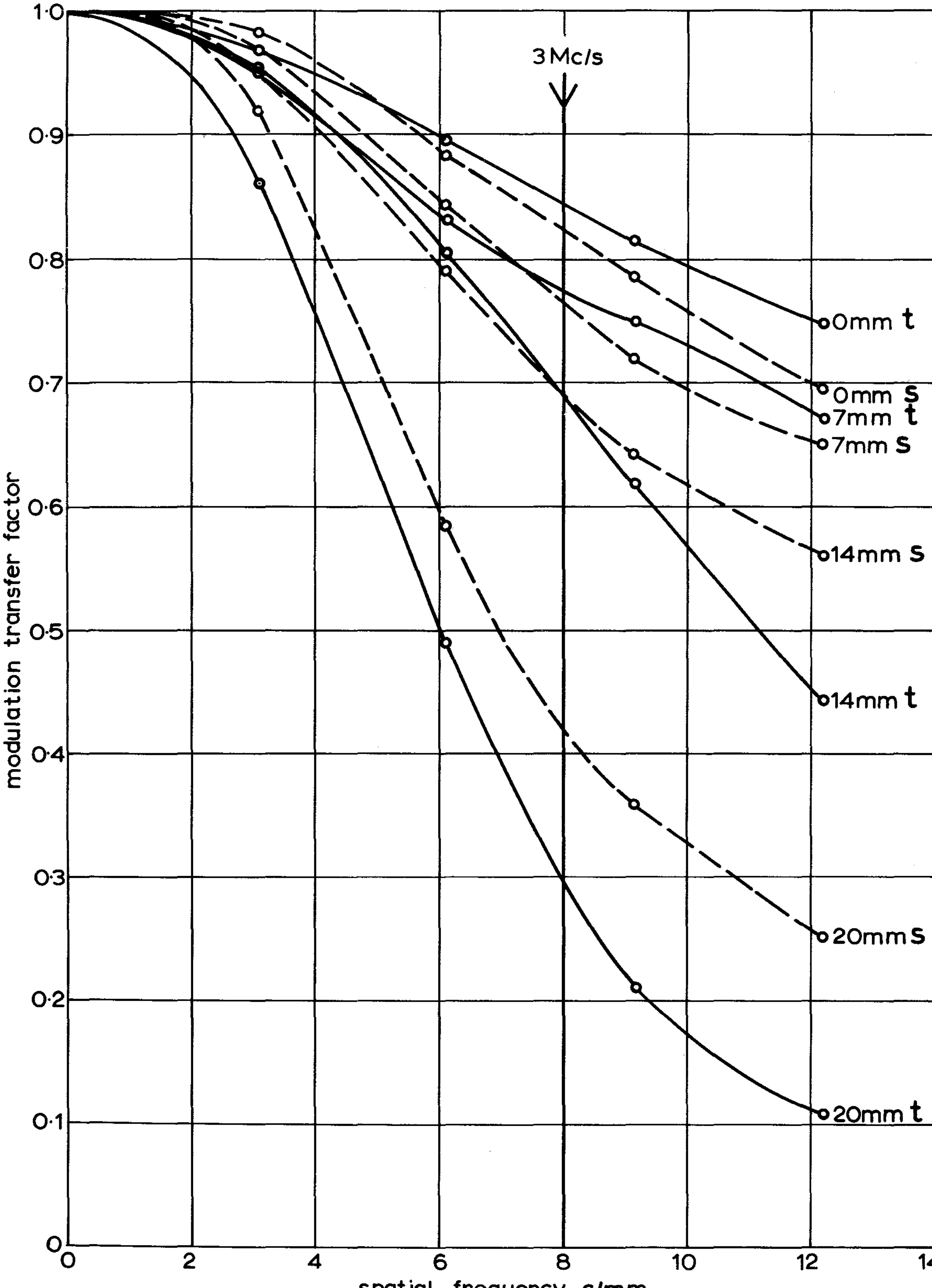

Fig. 3

Modulation transfer curves

focal length 86mm

aperture f/4

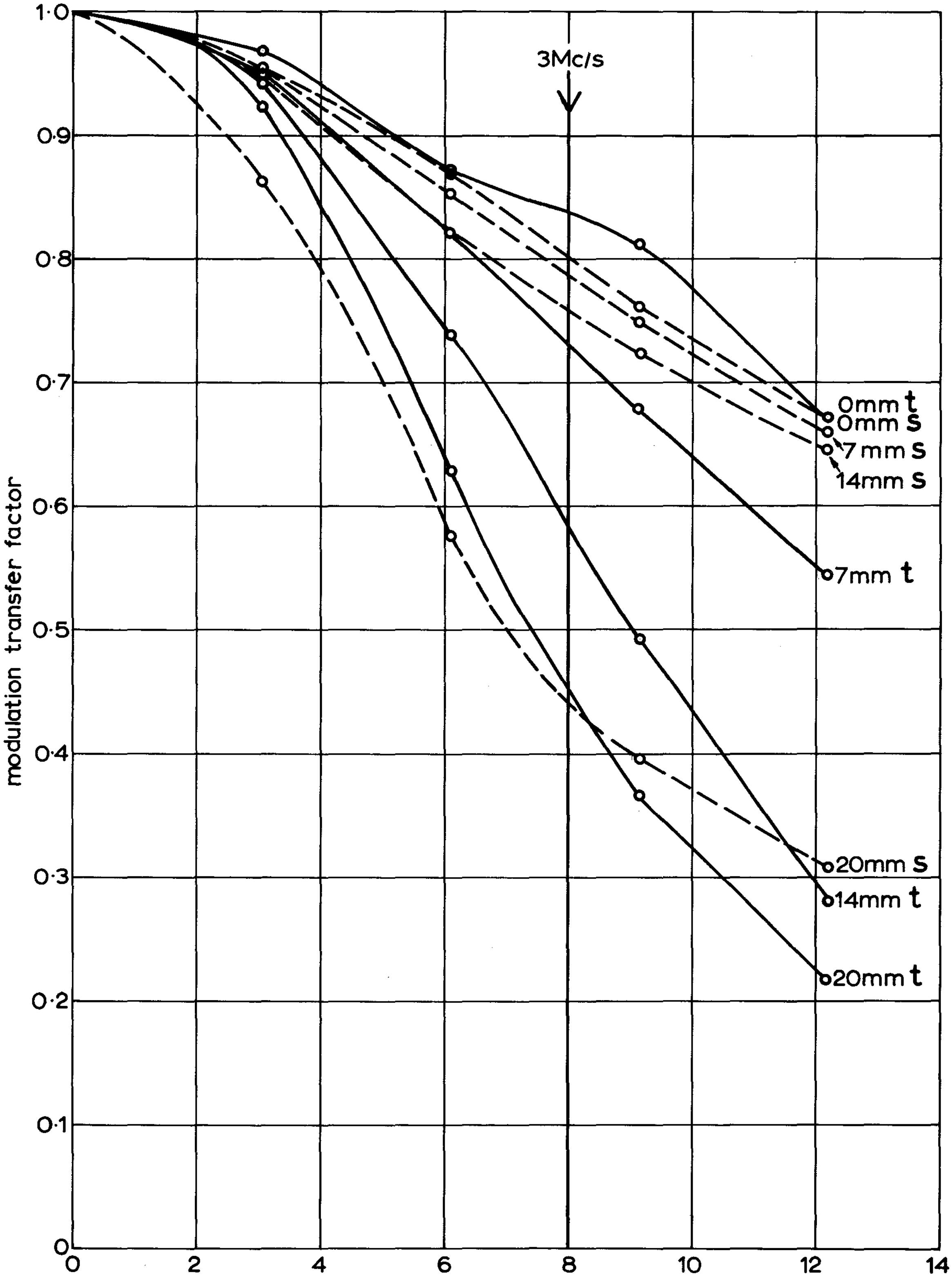

Fig. 4

Modulation transfer curves

focal length 126mm

aperture f/4

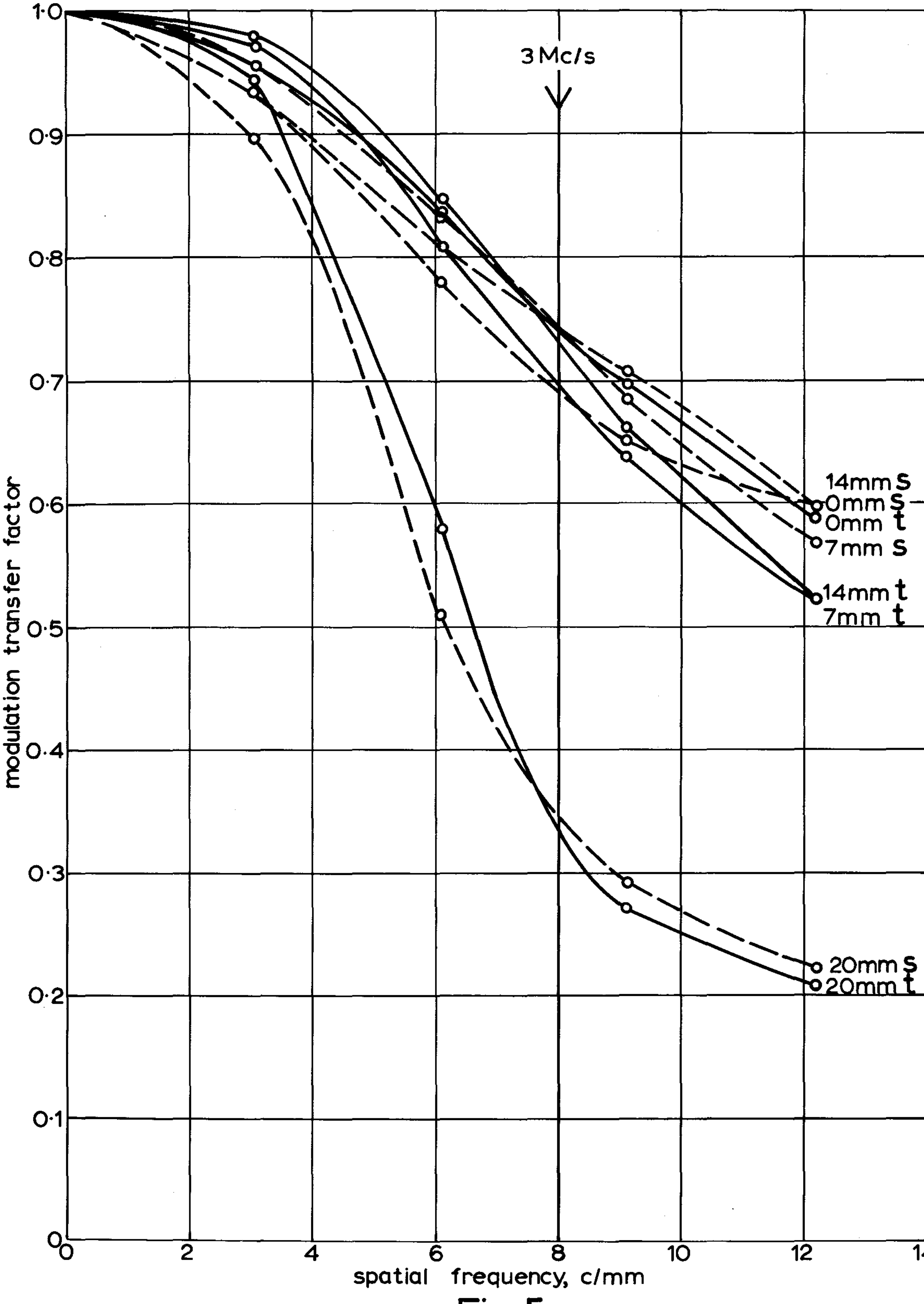

Fig. 5

Modulation transfer curves

focal length 186mm

aperture f/4

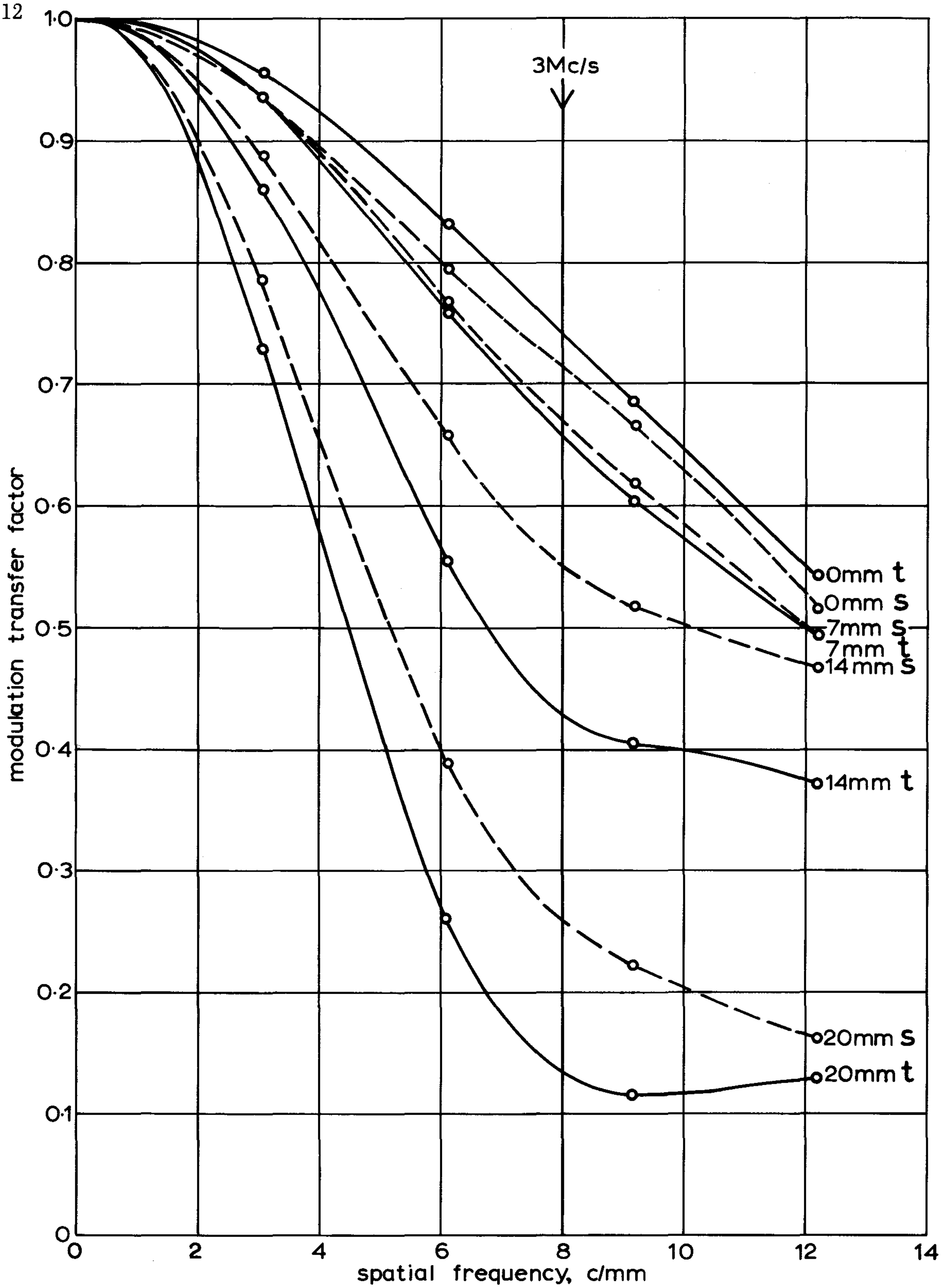

Fig. 6

Modulation transfer curves
focal length 272mm
aperture f/4

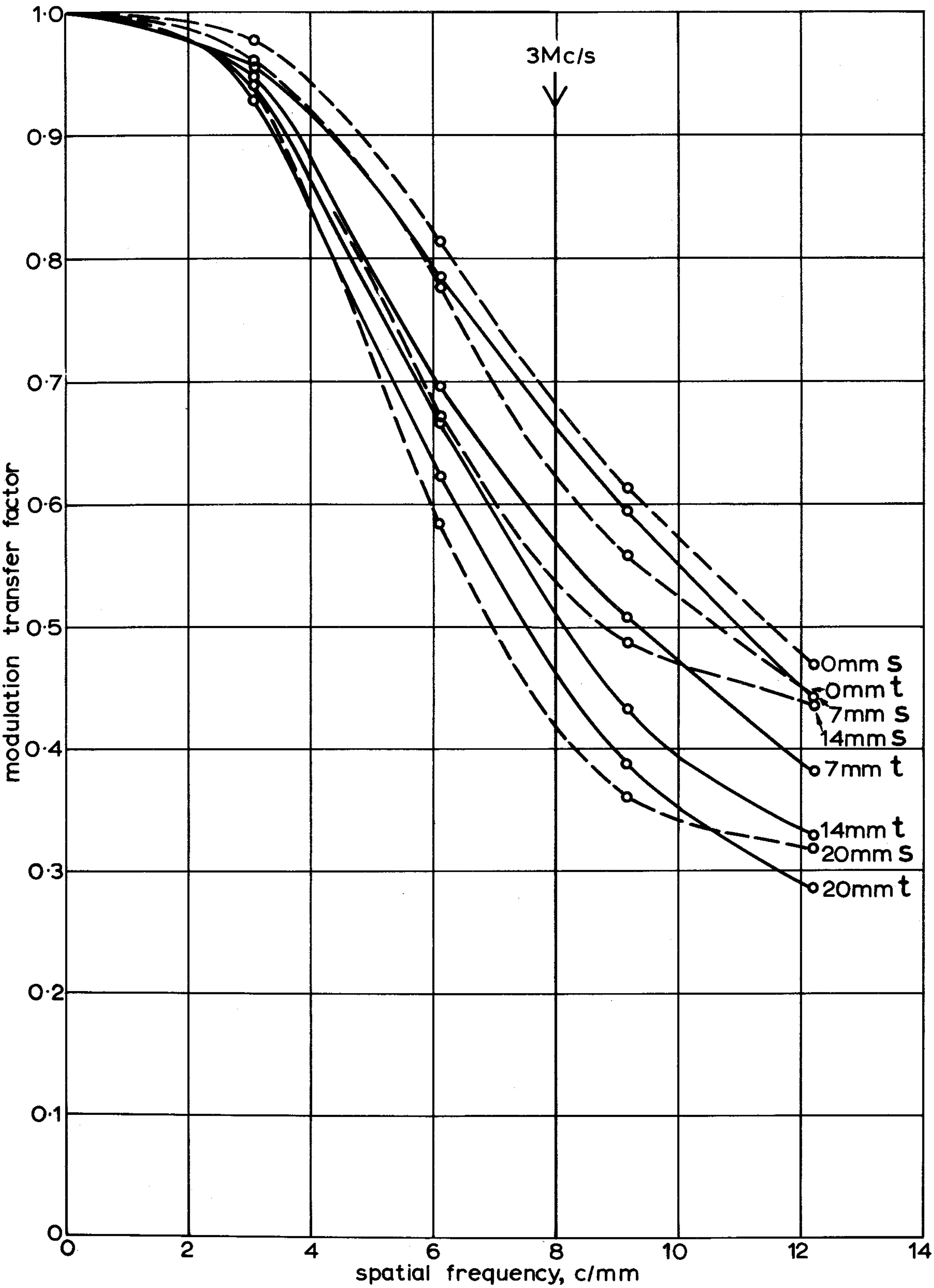

Fig. 7

Modulation transfer curves
focal length 400mm
aperture f/4

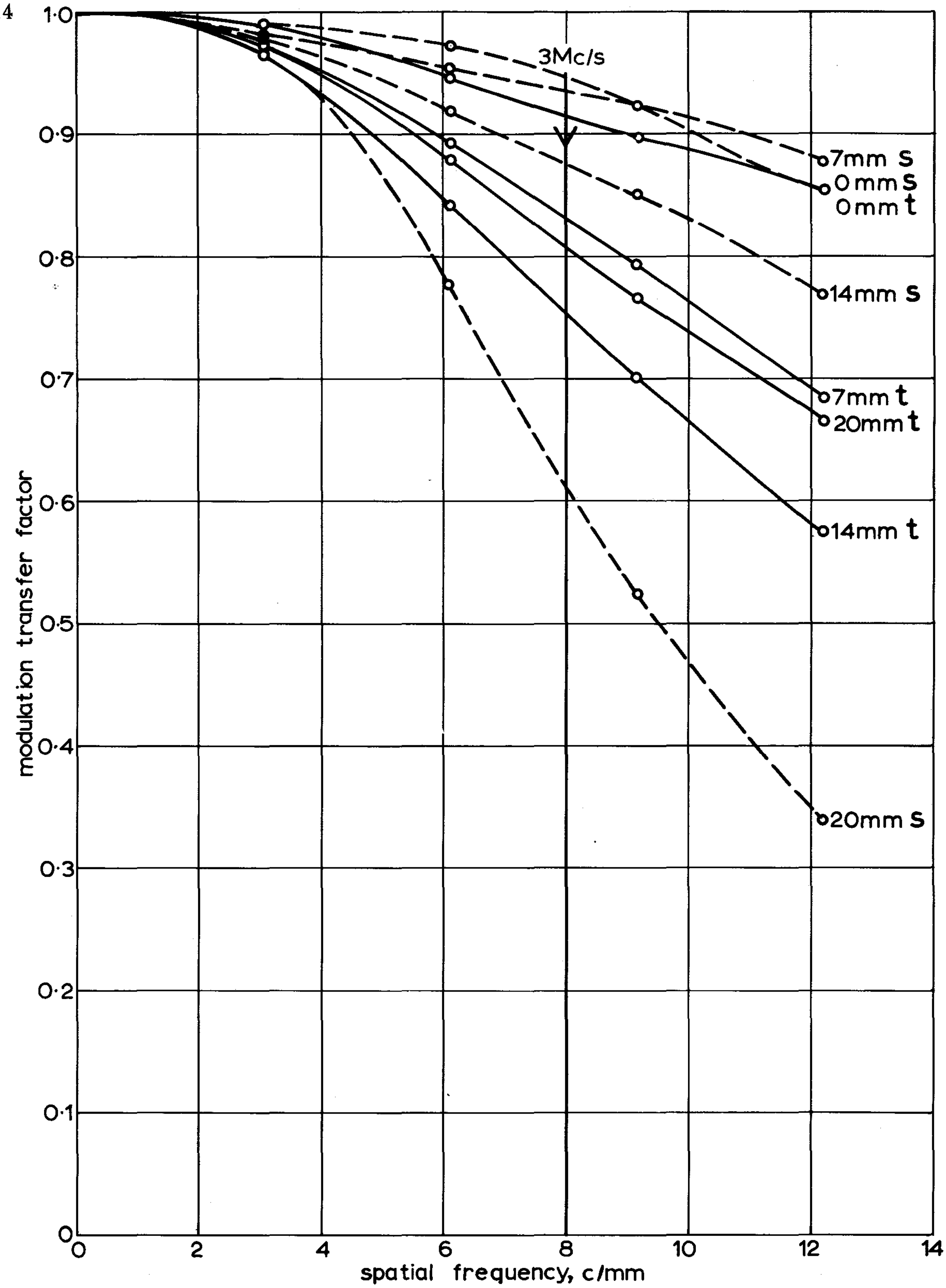

Fig. 8

Modulation transfer curves

focal length 40mm

aperture f/5·6

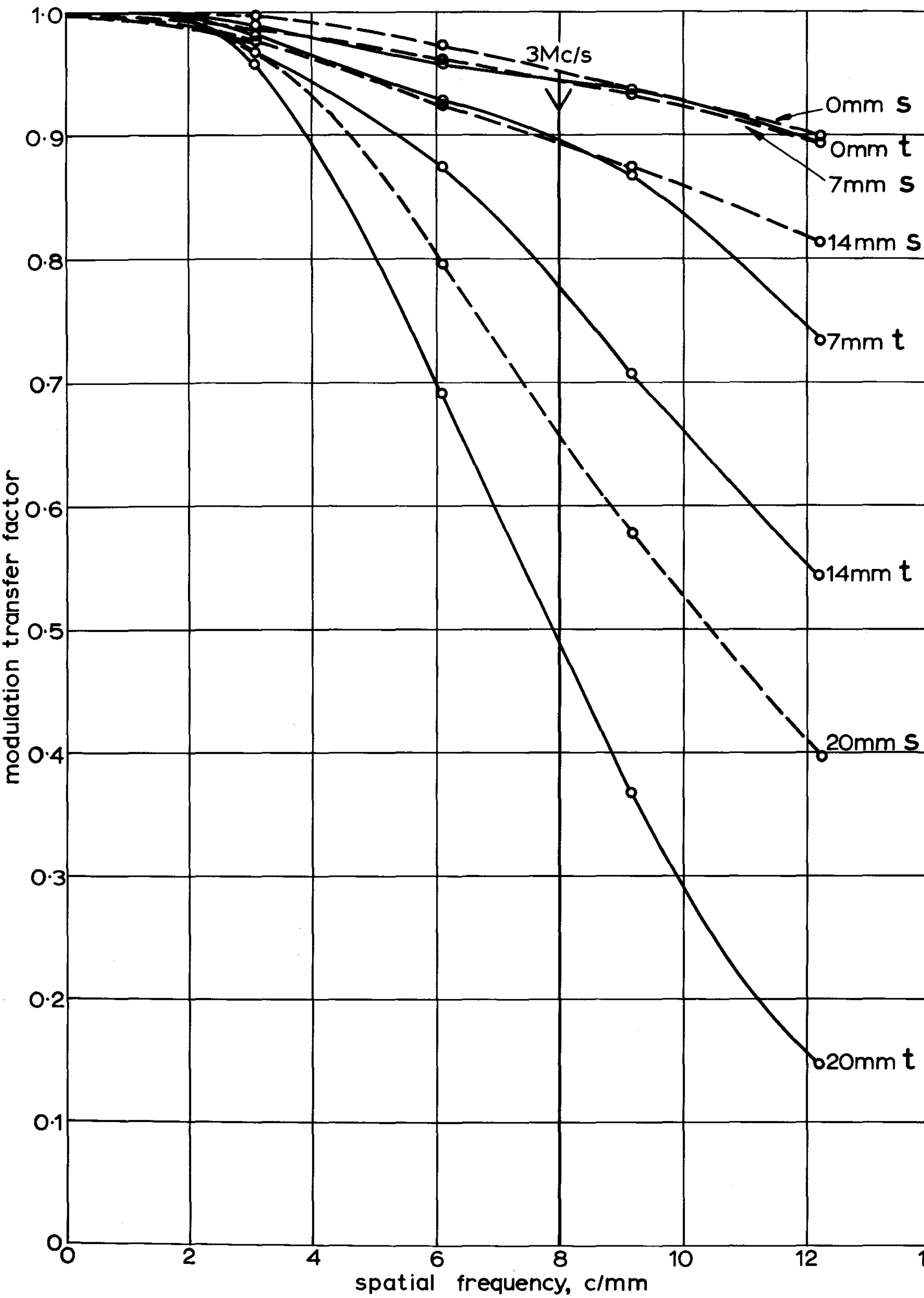

Fig. 9

Modulation transfer curves

focal length 59mm

aperture f/5·6

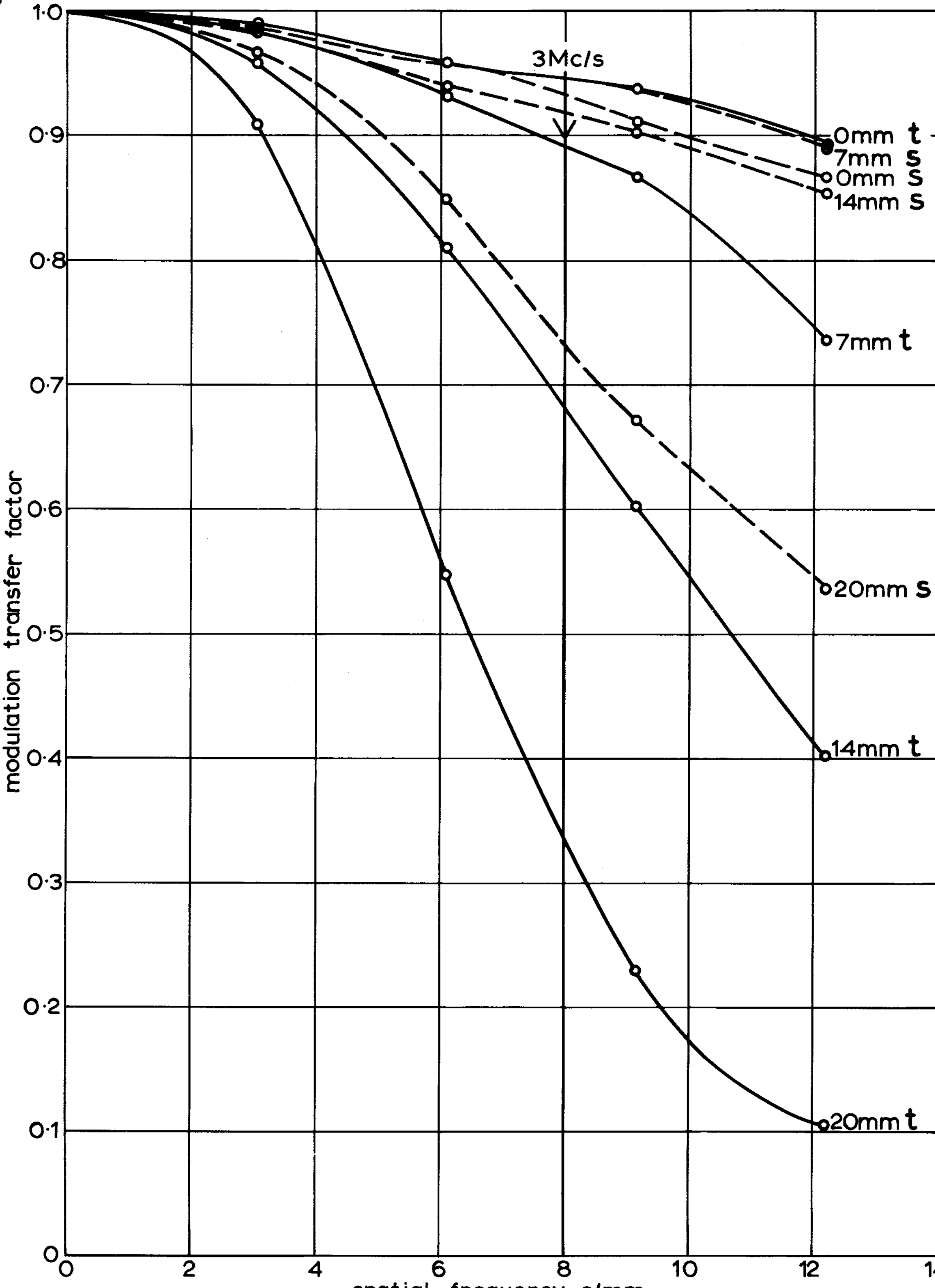

Fig. 10

Modulation transfer curves

focal length 86mm

aperture f/5·6

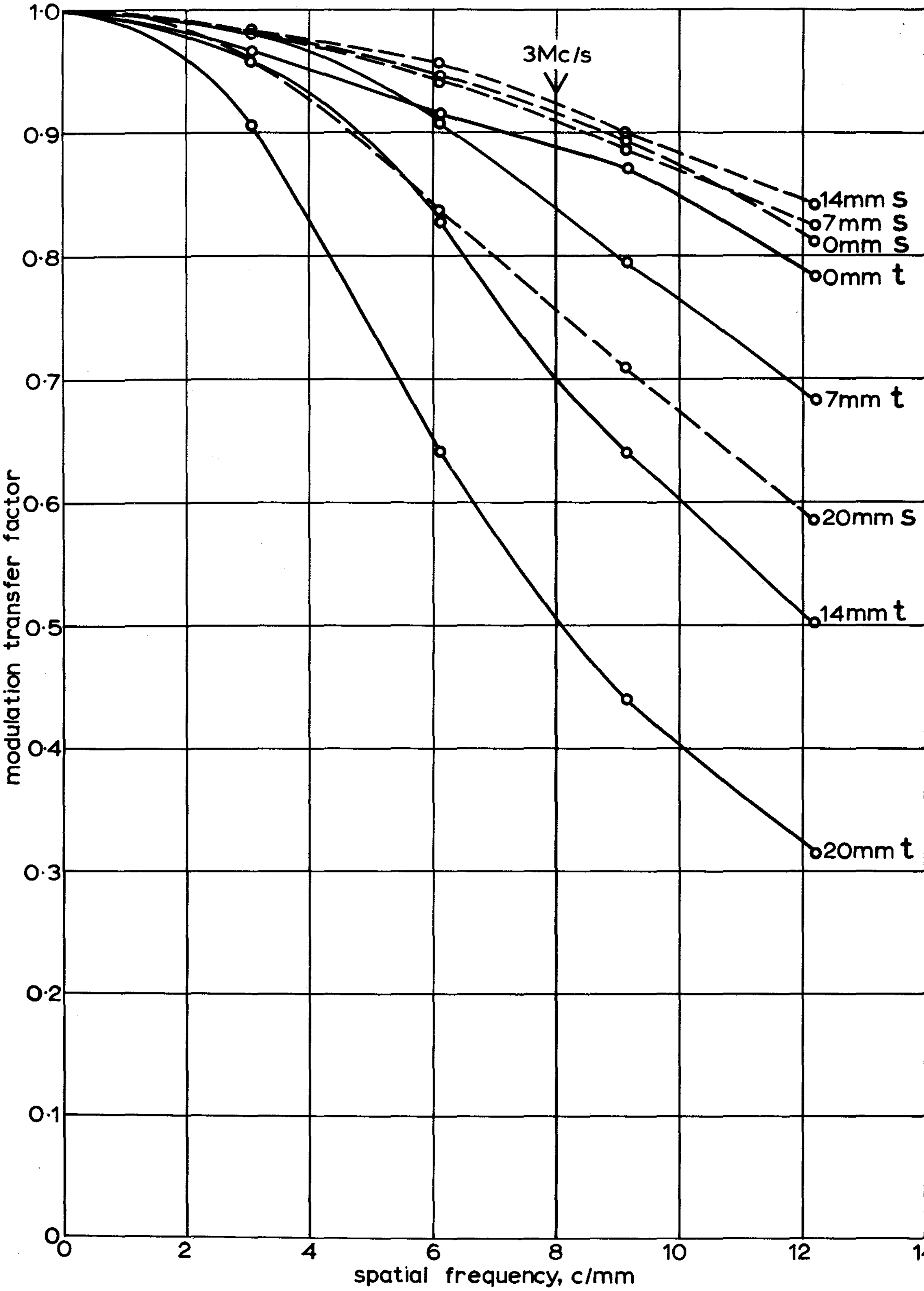

Fig. 11

Modulation transfer curves

focal length 126mm

aperture f/5·6

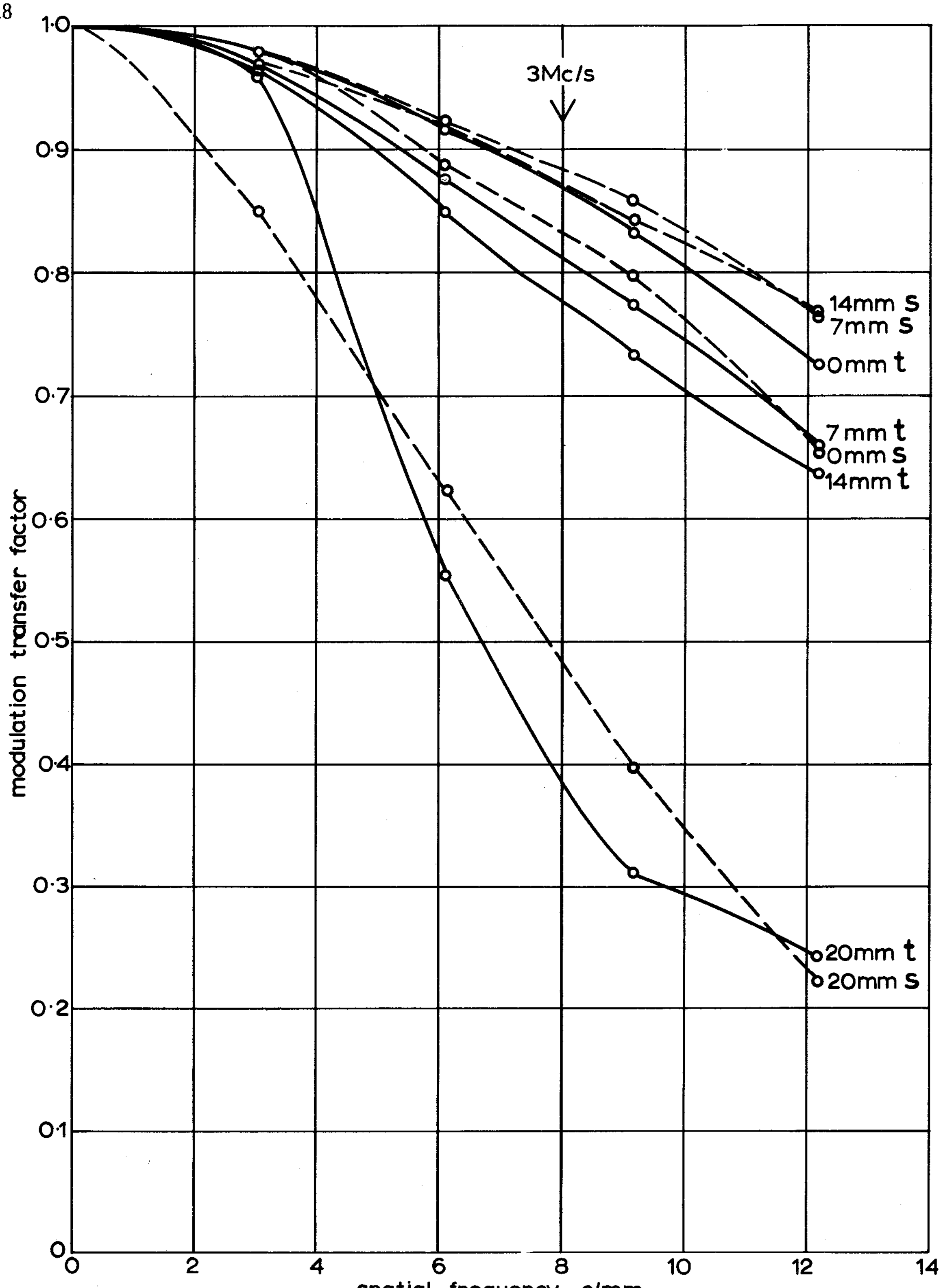

Fig. 12

Modulation transfer curves

focal length 186mm

aperture f/5·6

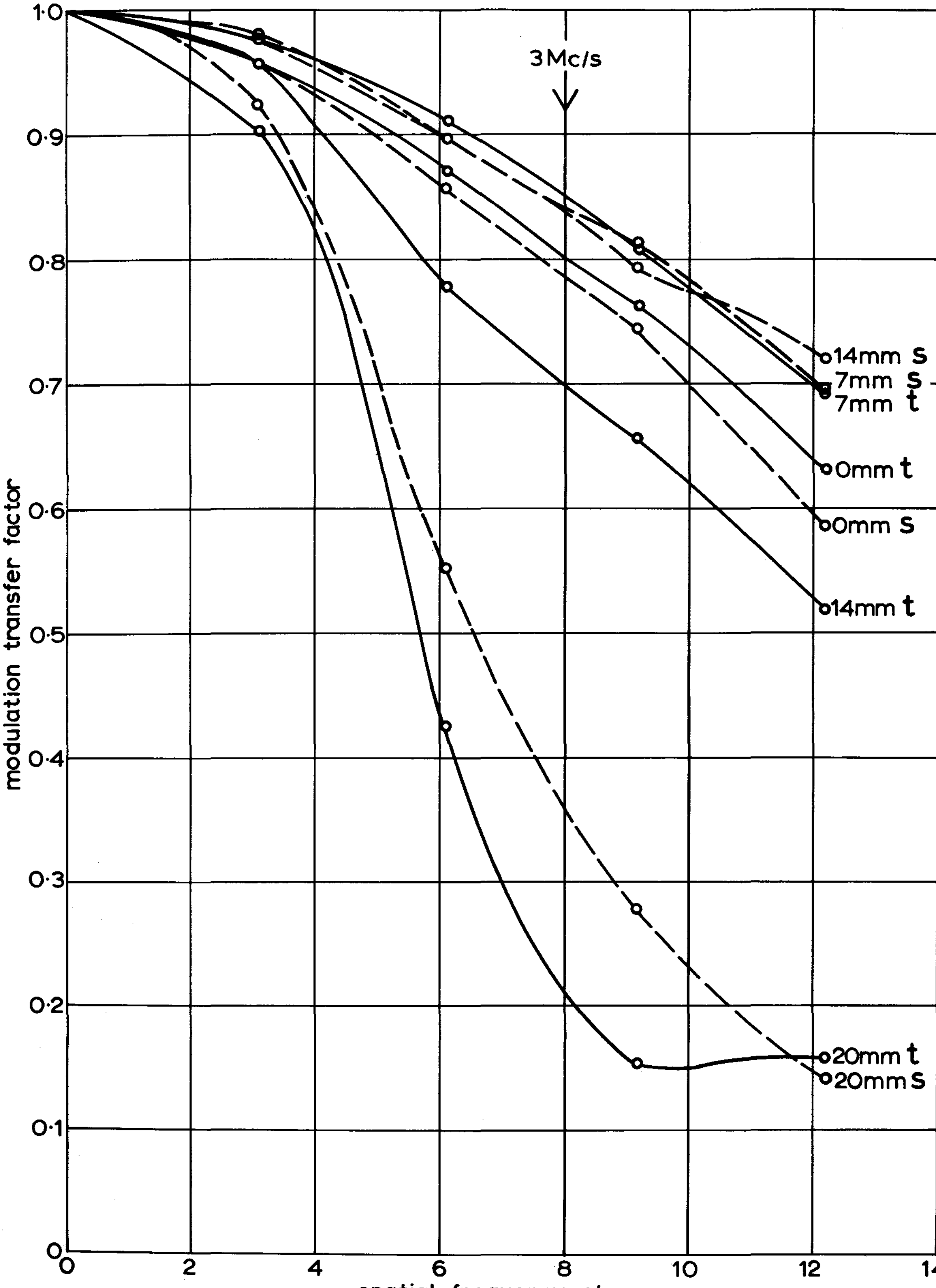

Fig. 13

Modulation transfer curves

focal length 272mm

aperture f/5·6

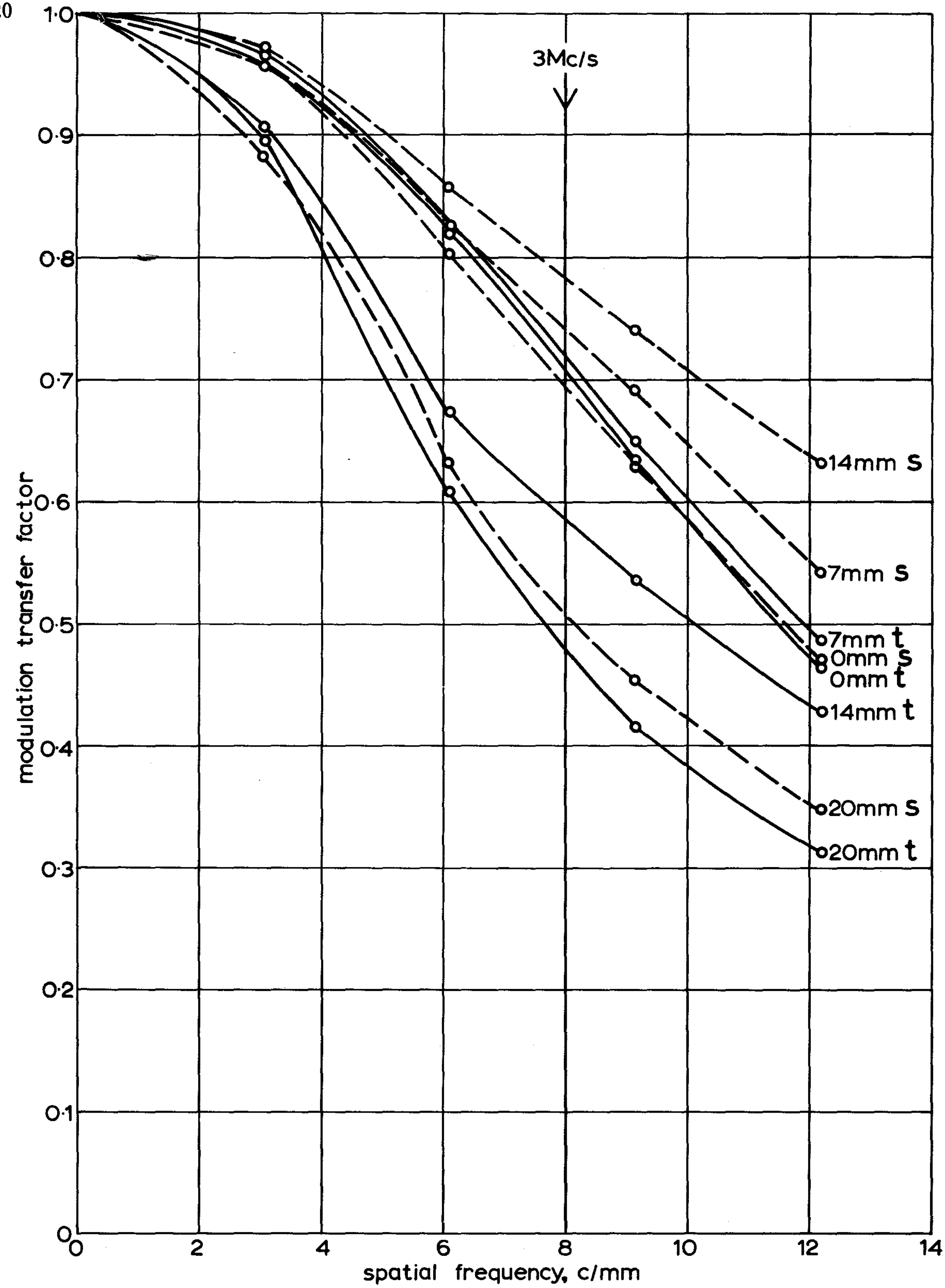

Fig. 14

Modulation transfer curves

focal length 400mm

aperture f/5·6

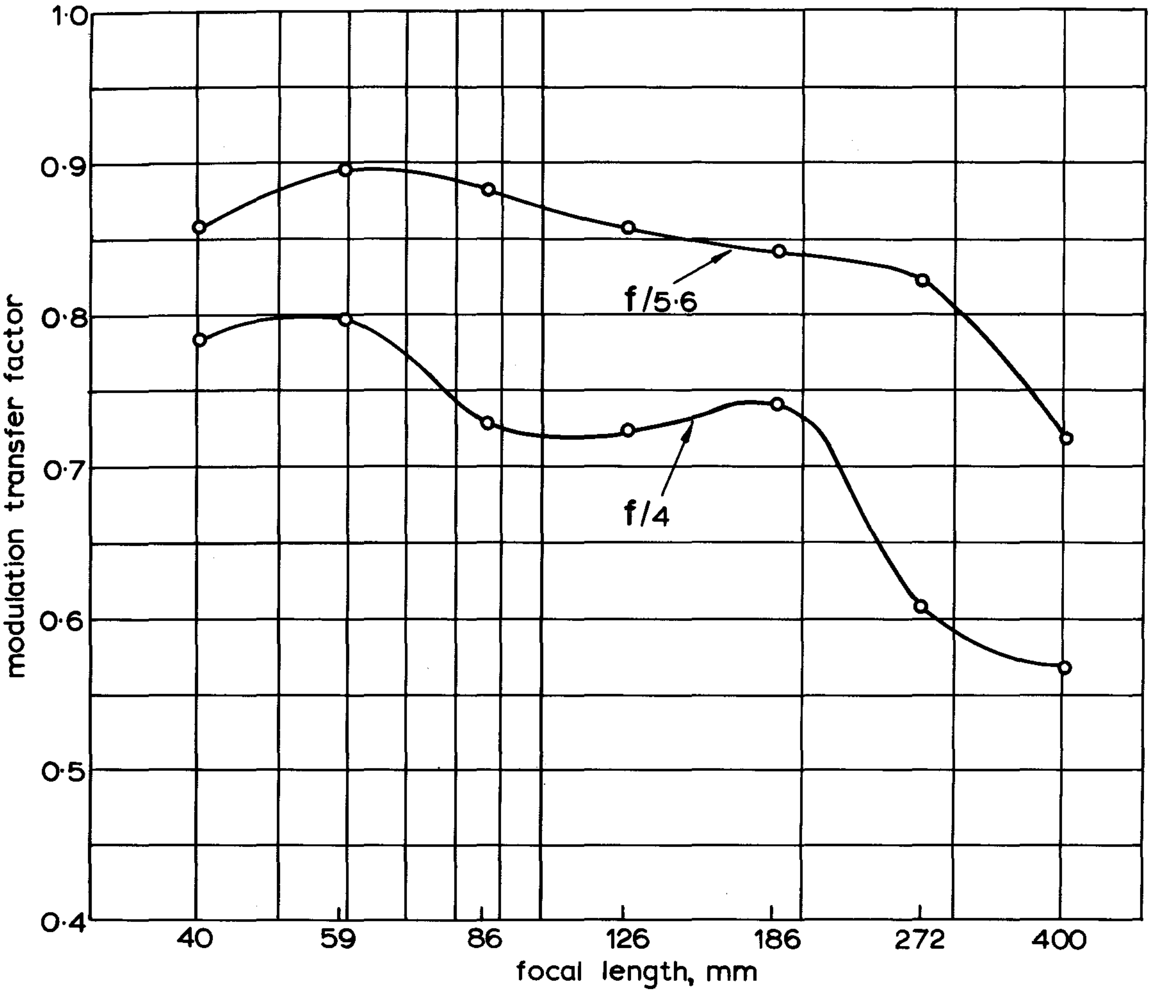

Fig. 15

Modulation transfer factor at 3Mc/s in the mid-field position
Average of the s and t modulation transfer factors.

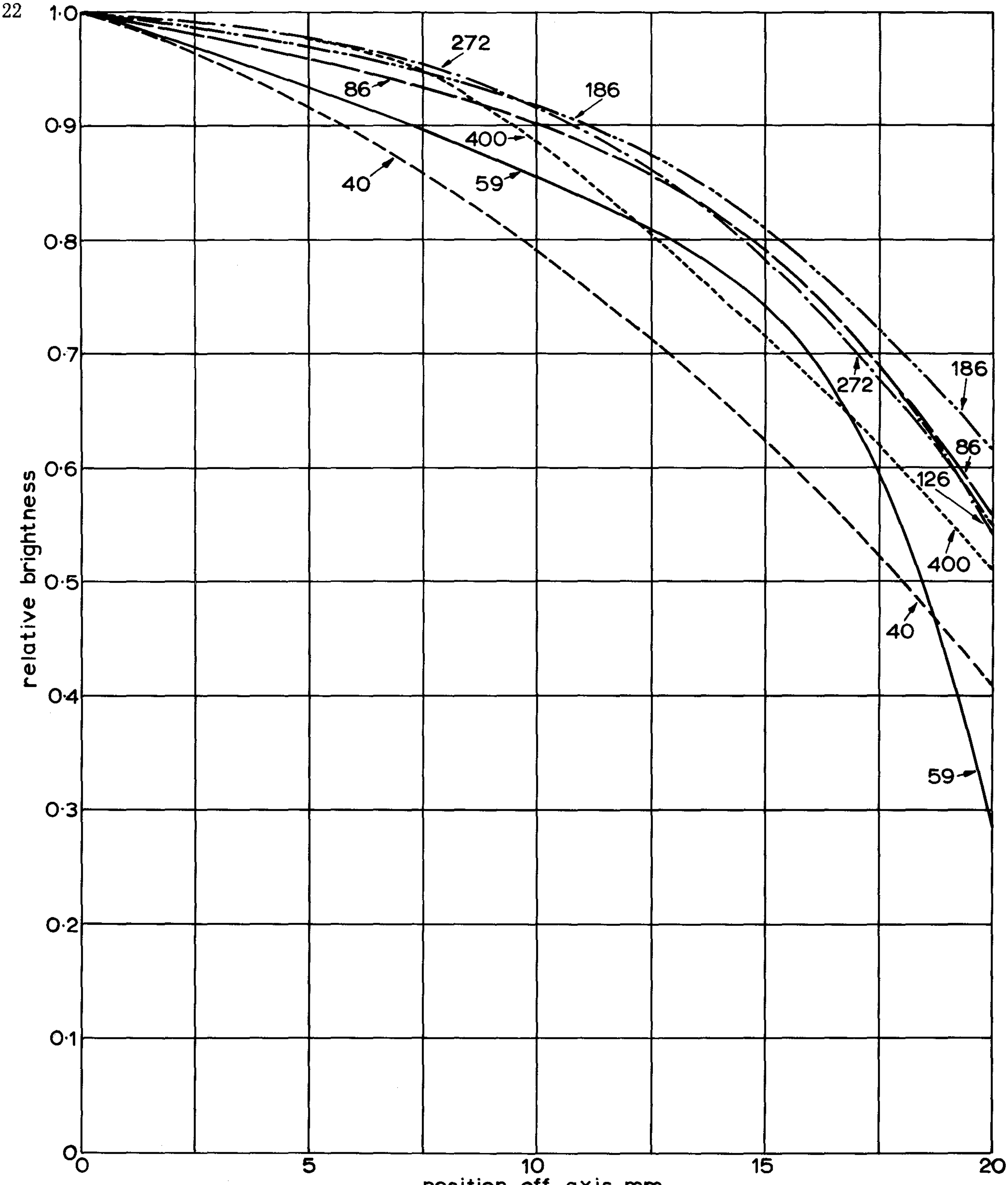

Fig. 16

Vignetting curves

aperture f/4

(numbers against curves are focal lengths)

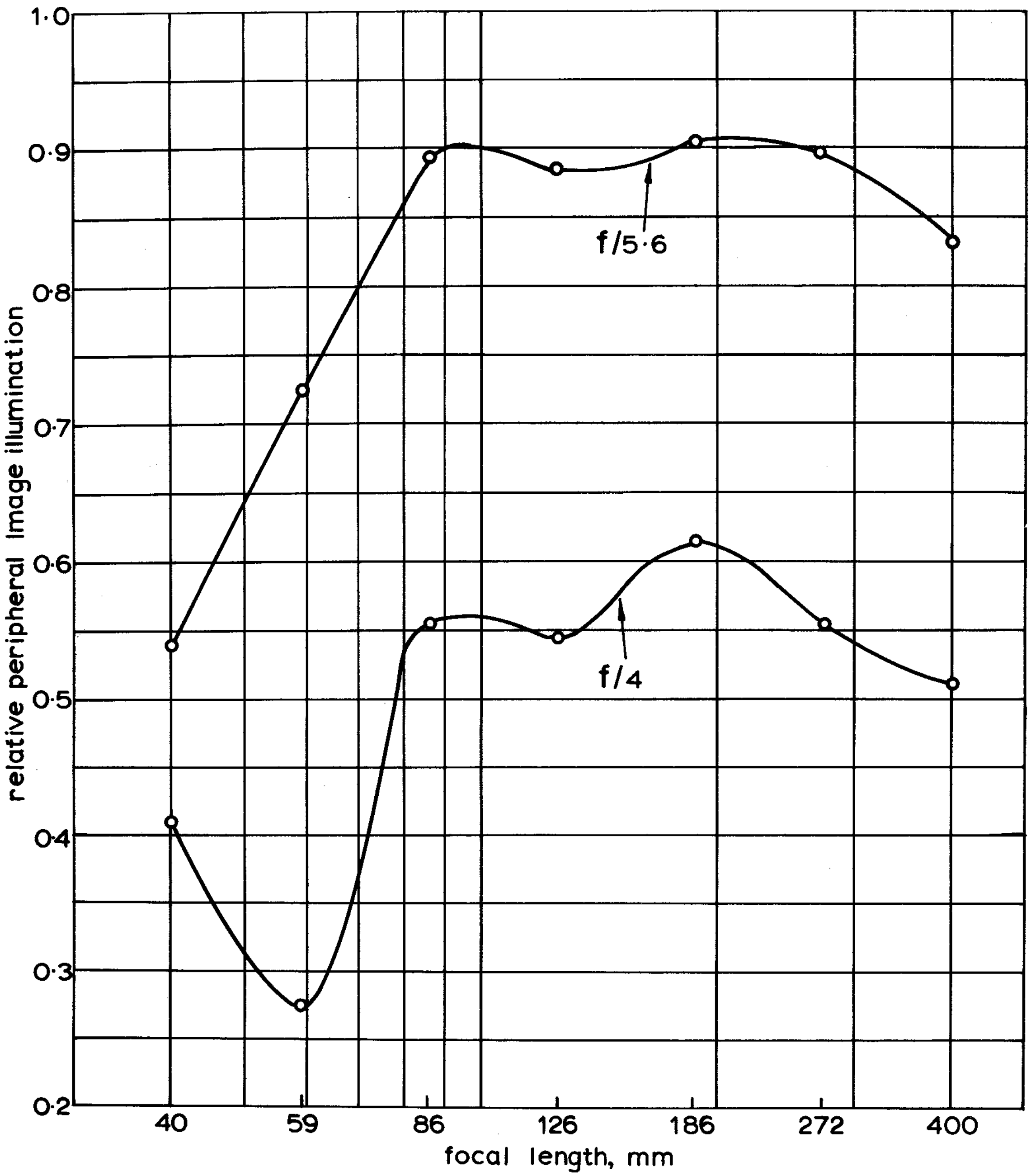

Fig. 17

Peripheral illumination at two apertures

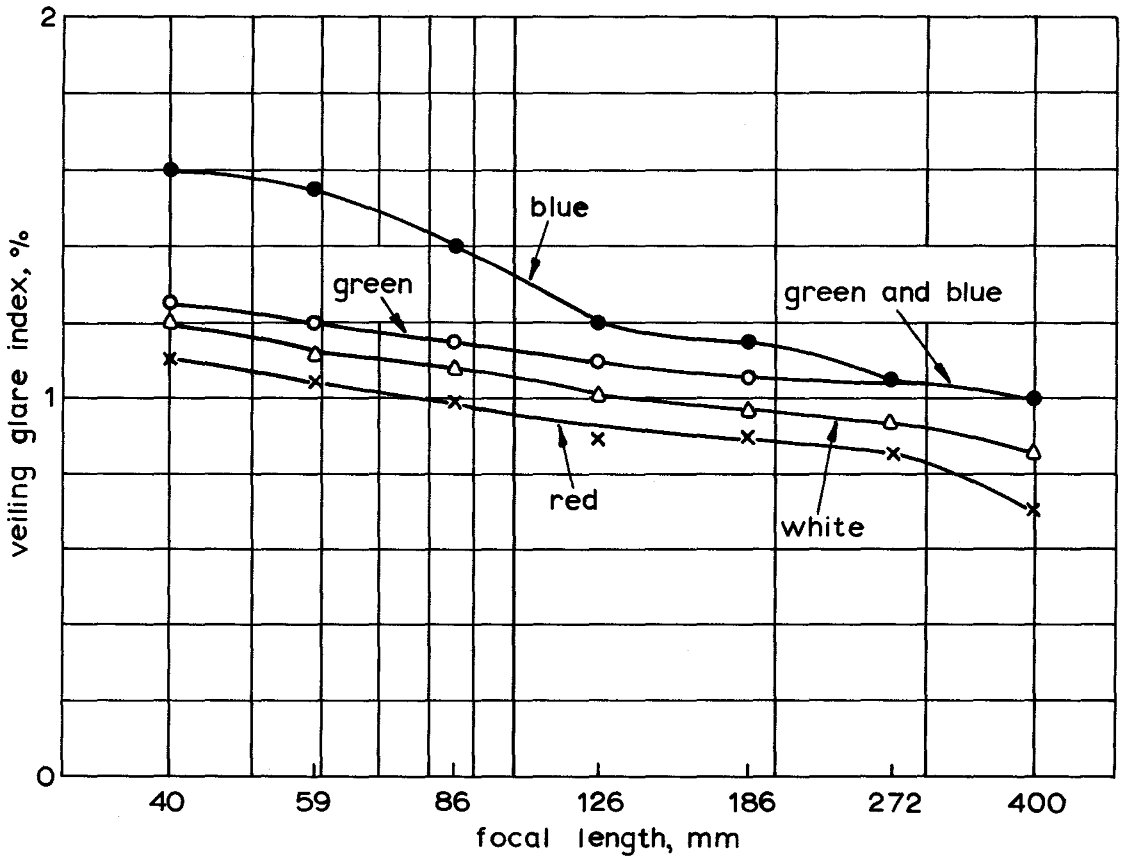

Fig. 18

Veiling glare index

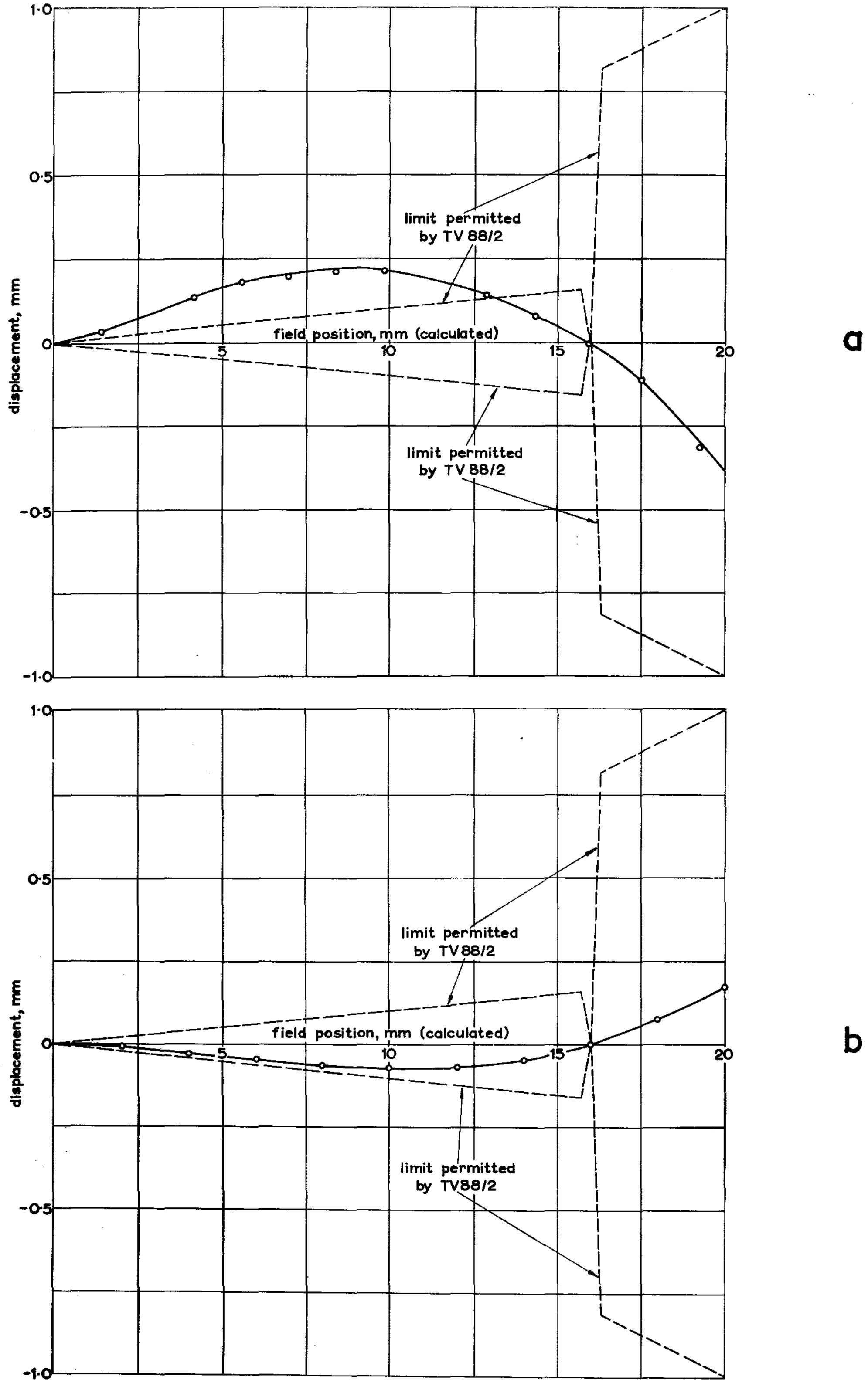

Fig.19 a Geometrical distortion at shortest focal length (f=40mm)
b Geometrical distortion at largest focal length (f=400mm)
test object at infinity

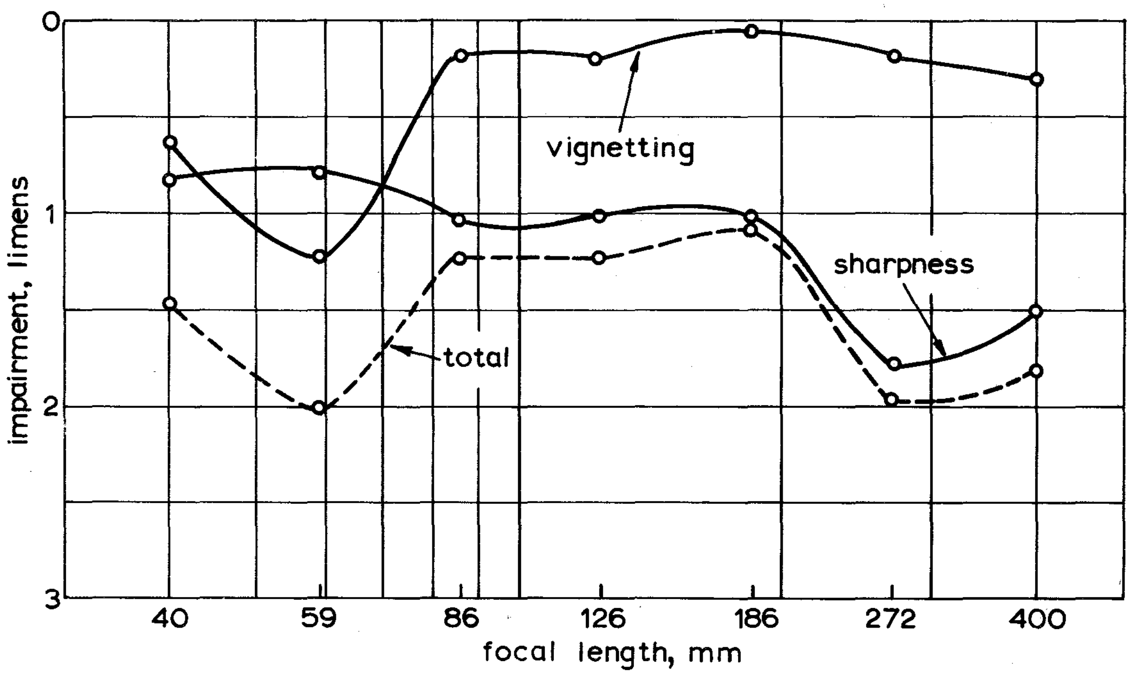

Fig. 20

Overall assessment
aperture f/4

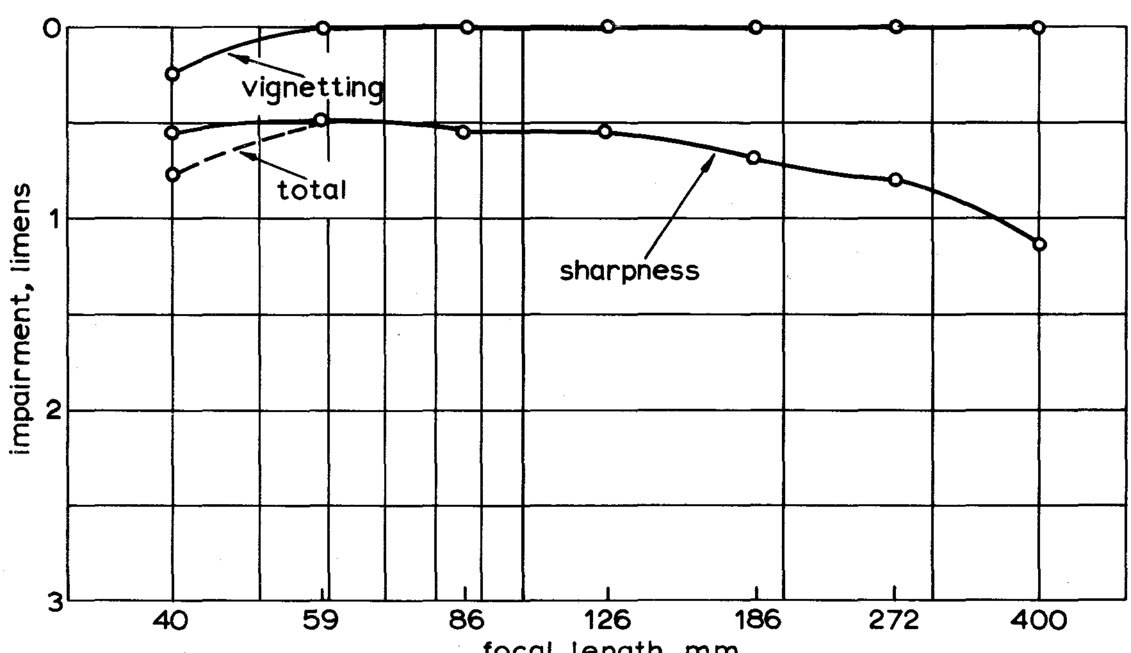

Fig. 21

Overall assessment
aperture f/5·6

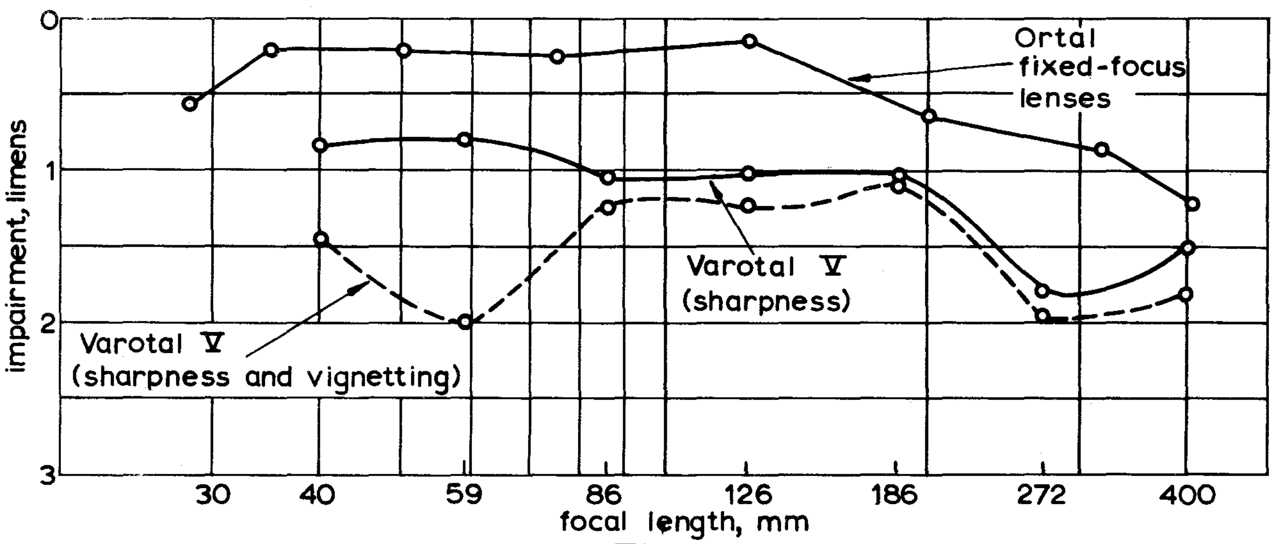

Fig. 22

Comparison of Varotal V zoom lens with fixed-focus Ortal lenses
aperture f/4

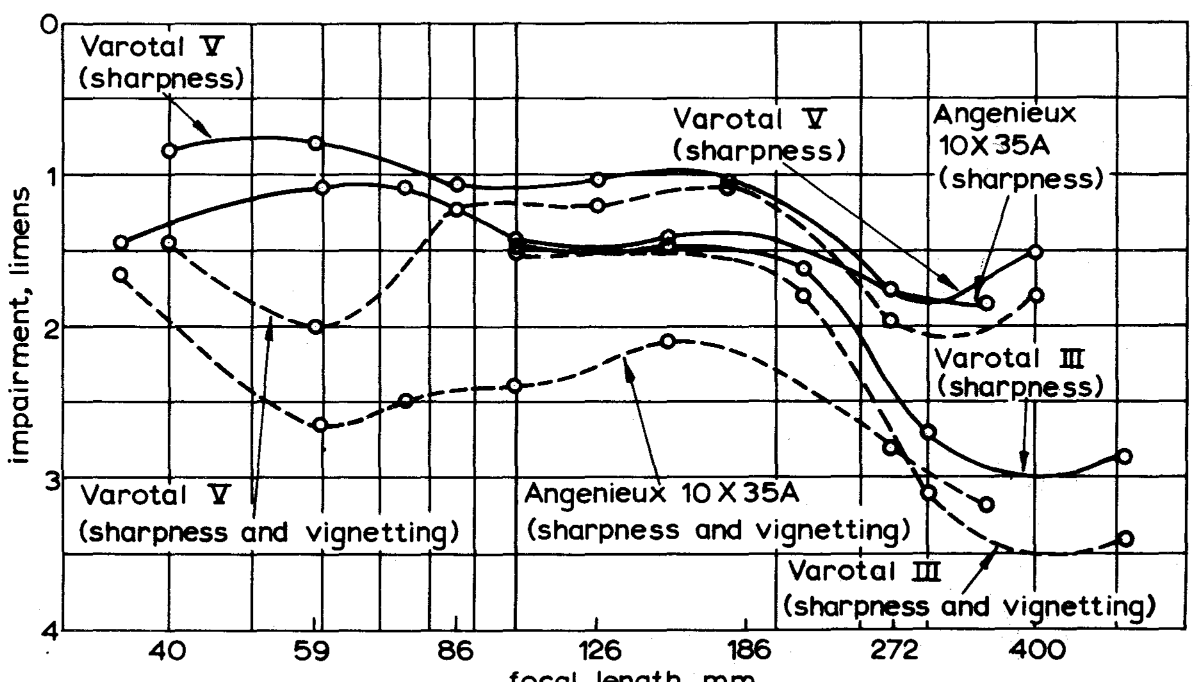

Fig. 23

Comparison of Angenieux 10X35A, Varotal III and Varotal V
all lenses at full aperture

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